RADAR INVESTIGATIONS OF ASTEROIDS

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Resolution of an asteroid's echoes in Doppler frequency and/or time delay provides 1-D or 2-D images, and hence direct measurements of the object's size and shape. Radar is sensitive to near-surface porosity, metal abundance, and structural scales larger than a few centimeters. Apart from physical characterization, radar is invaluable for refining orbits and prediction ephemerides, because delay-Doppler measurements are orthogonal to optical angle measurements and typically have a fractional precision between 105 and 10^{-8}. Echoes from 37 mainbelt asteroids (MB As) and 32 near-Earth asteroids (NEAs) have provided new information about these objects' physical and dynamical properties. Many of the most interesting results of this research involve the observations of NEAs. For example, in 1989, Arecibo observations of 4769 Castalia revealed it to consist of two km-diameter lobes in contact. In December 1992., during the closest approach to Earth of any known asteroid or comet until 2004, Goldstone observations of 4179 Toutatis revealed it, too, to be a contact binary, but with the lobes in a size ratio ~ 2/3. For each of these NEAs, it seems likely that the lobes once were separate and that they collided gently to produce the current contact-binary shape. Castalia and Toutatis, the first known examples of solid "double" objects in astronomy, are also the first several-km-sized bodies in the solar system of which images have been made. The Toutatis images place thousands of pixels on the object, providing fractional spatial resolution comparable to that of the images of951 Gaspra returned from the Galileo spacecraft in 1991. Inversion of all the (Goldstone and Arecibo) data may yield a model of Toutatis that is accurate to -100 m. Upgrades underway at Arecibo and Gold stone will dramatically y expand the range of those instruments and will optimize their imaging and astrometric capabilities. However, those instruments are heavily oversubscribed, and observation of more than a small fraction of the objects discoverable in proposed optical surveys will require new radar telescopes.

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